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EFFECTS OF THE OCTOBER 2003 MAGNETIC STORM OVER GPS SCINTILLATIONS AT THREE SITES IN THE BRAZILIAN TERRITORY

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Abstract

With the progress of the trans-ionospheric communications technologies, it is important to understand the medium where the signals propagate through and the external agents that affect this medium. In order to study the ionosphere in the South Atlantic Magnetic Anomaly area, the Southern Regional Space Research Center (CRSPE/INPE-MCT), installed at the Southern Space Observatory a GPS Receiving System ("Global Positioning System") to monitor the scintillations in the signals received from the GPS satellites due to Ionospheric Irregularities.

Solar activity observations from October 26 to 29, 2003 detected a very strong magnetic storm that caused subsequent effects in the Terrestrial Geophysics. Measurements of the magnetometers world net manifested large Earth magnetic field variations, characterizing a severe geomagnetic storm. The monitoring of the local ionosphere revealed intense GPS scintillations measurements over the São Martinho da Serra Southern Space Observatory (29,28° S, 53,82° W, dip latitude 18,57° S). Besides this, other two INPE's GPS receivers located in Cuiabá (15,45° S, 56,46° W, dip latitude 6,1° S) and in São Luís (2,57°S, 44,00° W, dip latitude 1,3° S) detected similar perturbations in the same period.

This work presents the GPS signals behavior during the magnetic storm of October 26-29, 2003, in these three sites over the Brazilian territory. The GPS scintillations are compared with the magnetic indices.

GPS System in Brazil

Currently, the Division of Aeronomy - DAE/INPE, in collaboration with the University of Cornell (U.S.A.), keeps 13 GPS receivers installed in 8 sites over the Brazilian Territory. These receivers are scintilation monitors in amplitude (SCINTMON) of the L1 carrier transmitted for satellites GPS (Beach and Kintner, 2001). Figure 1 shows the distribution of receivers SCINTMON over the Brazilian Territory and Table 1 indicates the coordinates of these stations. For this study we selected three sites: São Martinho da Serra, where is located the Southern Space Observatory - OES/CRSPE/INPE - MCT (Figure 2) that is close to the southern crest of the Equatorial Anomaly, Cuiabá, that is located in between the Anomay Crest and the Magnetic Equator , and São Luís, that is located under the the Magnetic Equator.

Table 1. – Coordinates of the Stations GPS in Brazilian territory.

Station	Geog. Lat.	Geog. Long.	Magnetic Declination	Dip Lat.
S.Martinho da Serra	29,28° S	53,82° O	12,90° O	-18,57
S.J.dos Campos	23.07° S	45,86° O	20,03° O	-18,01
Cachoeira Paulista	22.57° S	45.0 0° O	20,54° O	-18, 12
Palmas	26,36° S	51,98° O	15,36° O	-17,27
Cuiabá	15,45° S	56,07° O	11,98° O	-6,1
São Luís	02,57° S	44,2° O	20,74° O	-1,3
Manaus	03,08° S	59,9° O	11,96° O	-8,79

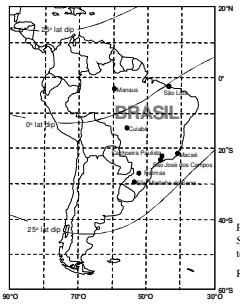

Figure 1 – Location of the SCINTMON receivers in Brazilian territory.

Reference: Rodrigues, 2003.

Observatory SSO Site

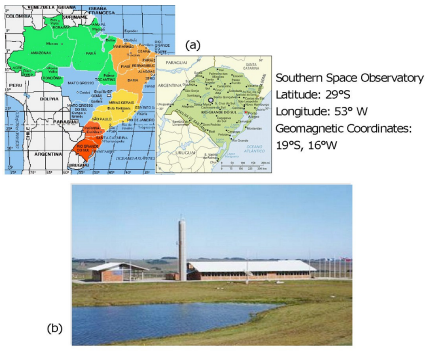

Figure 2 – (a) Localization in Brazilian terrritory and **(b)** view main of the biulding of the Southern Space Observatory - SSO/CRSPE/INPE-MCT, install stations 'S' of the GPS System.

Data Analysis

On October 29, 2003 it was detected a severe magnetic storm, and the SSC occurred approximately at 0600 UT. This storm lasted from 29 to October 31, 2003, and in this period the values of the Kp index reached 9 and remained with values larger than 4 from 06 AM on October 29 up to 06 PM on October 31, as illustrated in the Figure 3. The Dst index had a negative incursion of – 401 nT on October 29, as shown in the Figure 4. To analyse the effect of this severe storm over the GPS scintillations at the 3 sites specified above, it was used the scintillation index S4, calculated for each minute using the SCINTMON data for the day 26, that was a quiet day used as reference, and for the disturbed day 29.

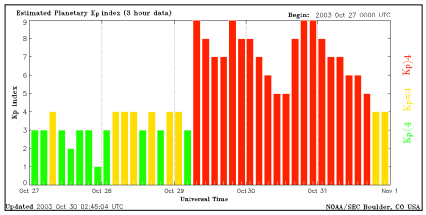

Figure 3 – Kp Index from from October 27 to 31, 2003.

Adapted from http://sec.noaa.gov/ftpdir/plots/2003_plots/kp/20031029_kp.gif

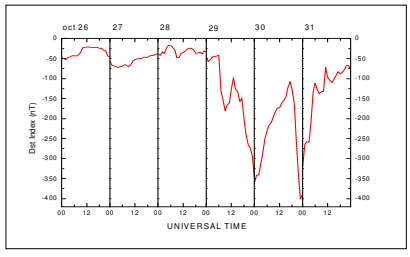

Figure 4 –Dst Index from October 26 to 31, 2003.

Adapted from http://swdcwww.kugi.kyoto-u.ac.jp/dstdir/dst1/p/dstprov200310.html

Effects of the storm over the GPS data

The effects of the October, 2003 Magnetic Storm over the GPS scintillations, represented by the S4 index, are presented in the Figure 5. On October 26, 2003, during quiet magnetic activity, we observed (Figure 5a) no scintillations at São Martinho da Serra that is located close to the crest of the Equatorial Anomaly and scintillations were observed at Cuiabá and São Luís (Figure 5c and 5e), that are closer to the magnetic. On October 29, 2003, during high magnetic activity period, we observed a high index of scintillations (Figure 5b) in São Martinho da Serra, while weak scintillations were observed in Cuiabá and São Luís (Figure 5d and 5f). These observations give evidence of the displacement of the Equatorial Anomaly crests to larger latitudes due to the penetration to the equator of a large eastward electric field from the magnetosphere during this storm. During this storm the Equatorial Anomaly crest probably reached São Martinho da Serra and increased the background ionization and increased the scintillation amplitudes (de Paula et al, 2003). As this ionization was removed from equator and lower latitudes during this storm the scintillation amplitudes at Cuiabá and São Luís were smaller.

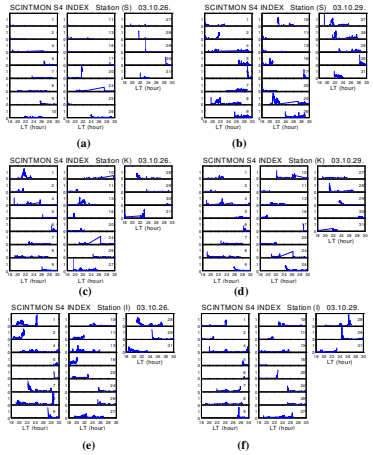

Figure 5 – S4 indices for quiet day (26) and disturbed day (29). 5**(a)** and 5**(b)**, are the S4 for the GPS receivers in São Martinho da Serra, RS, Brazil. 5**(c)** and 5**(d)** are the S4 for the GPS receivers in Cuiabá, MT, Brazil.5**(e)** e 5**(f)** are the S4 for the GPS receivers in São Luis, MA, Brazil.

Conclusions

- During the reference quiet day (26) we observed stronger scintillations at São Luís (magnetic equator) and Cuiabá (between the equator and the Equatorial Anomaly) compared to São Martinho da Serra (close to the crest of the Equatorial Anomaly).

- During the severe storm of October 29 the scintillations were stronger at São Martinho da Serra.

- We suggest that during the storm day the Equatorial Anomaly crest moved over São Martinho da Serra (extreme south of Brazil), due to the penetration to equator of one magnetospheric eastward penetration electric field, increasing the background ionization and amplifying the scintillation amplitude at this site.

- Analysis of others sounders data (digisonde, VHF radar) during this storm are underway.

References:

(1) Abdu, M. A.; Muralikrishna, P.; Batista, I. S.; Sobral, J. H. A. **Rocket observation of equatorial plasma bubbles over Natal, Brazil, using a high-frequency capacitance probe**. **Journal of Geophysical Research**, , v. 96, n. A5, p. 7689-7695, 1991.
(2) Beach, T. L.; Kintner, P. M. Development and Use of a GPS Ionospheric Scintillation Monitor. **IEEE Transactions on Geoscience and Remote Sensing**, v. 39, n. 5, p. 918-928, May 2001.
(3) De Paula, E.R.; Rodrigues, R. S.; Iyer, K. N.; Abdu, M. A.; Kintner, P. M.; Ledvina, B. M., and Kiç, H. Equatorial Anomaly Effects on GPS scintillations in Brazil, Adv. Space Res. Vol. 3, pp. 749-754, 2003.
(4) Kelley, M. C. **The earth's ionosphere.** New YorK, Cornell University, p. 122, 1989.
(5) Rodrigues, F. S.; **Estudo das Irregularidades Ionosféricas Equatoriais utilizando sinais GPS**, Dissertação de mestrado, INPE, São José dos Campos, 2003.